Technical Memorandum

October 10, 2002

To: File

From: William B. Kuykendal

Subject: Decisions on Final AP-42 Section 13.2.1 "Paved Roads"

In October 2001, EPA published a draft Section 13.2.1 "Paved Roads" for AP-42 and requested comments. This memorandum summarizes the comments received and presents EPA's decisions and rational supporting these decisions leading to the final section.

Mr. Ronald Myers submitted comments dealing with the moisture correction term. Mr. Myers selected 12 cities representing various climate regions from the *Solar and Meteorological Surface Observation Network 1961 - 1990* CD-ROM. He used precipitation data from these cities to evaluate the comparability of the two options presented in the draft section. His analysis showed that the Daily Option (Option 1) produced an emission reduction factor that was twice the value produced by the Hourly Option (Option 2). EPA agrees that the Daily Option and Hourly Option should produce comparable results. EPA believes that the Hourly Option should be more precise. Therefore, EPA has revised the moisture correction term for the Daily Option to conform with the Hourly Option as follows:

Draft Daily Moisture Correction: $(1 - P/2N)$

Final Daily Moisture Correction: $(1 - P/4N)$

Where:

P = number of days with at least 0.254 mm (0.01 in) of precipitation during the averaging period

N = number of days in the averaging period

Mr. Myers also suggested that EPA include both moisture correction options in the final AP-42 section and let the user choose which one to use. There is also good justification for retaining the hourly equation from the perspective of emissions and air quality modeling. In the modeling applications, hourly temporal resolution can be important. Therefore, EPA will publish both options in the final section.

Mr. Myers also presented a rationale that would account for the effect of precipitation reducing silt concentration by washing the road surface. Additionally, he considered the effect of residual moisture after the precipitation event having a mitigative effect. He included an analysis of a hypothetical situation believed to be typical that showed a 20% residual effect of moisture for the Hourly Option. Dr. Richard Countess (see following) also commented that the moisture correction should have provision for the mitigative effect lasting beyond the precipitation event. Based on these comments, EPA has accepted Mr. Myers' analysis and increased the hourly moisture correction term by 20% as follows:

Draft Hourly Moisture Correction: (1 - P/N)

Final Hourly Moisture Correction: (1 - 1.2 P/N)

Where:

P = number of hours with at least 0.254 mm (0.01 in) of precipitation during the averaging period

N = number of hours in the averaging period

Note: In the final hourly moisture correction term, the 1.2 multiplier is applied to account for the residual mitigative effect of moisture. For most applications, this equation will produce satisfactory results. However, if the time interval for which the equation is applied is short, e.g., for one hour or one day, the application of this multiplier makes it possible for the moisture correction term to become negative. This will result in calculated negative emissions which is not realistic. Users should expand the time interval to include sufficient "dry" hours such that negative emissions are not calculated. For the special case where this equation is used to calculate emissions on an hour by hour basis, such as would be done in some emissions modeling situations, the moisture correction term should be modified so that the moisture correction "credit" is applied to the first hours following cessation of precipitation. In this special case, it is suggested that this 20% "credit" be applied on a basis of one hour credit for each hour of precipitation up to a maximum of 12 hours.

Dr. Richard Countess offered several comments regarding moisture correction, the impact of the amount of precipitation, consistency with unpaved roads regarding the effect of moisture and how to account for vehicle weight. Dr. Countess agreed that a moisture correction term is appropriate for paved road emissions. He suggested that EPA make a distinction between rain and snow, stating that snow would form more of a physical barrier to emissions. This is probably true, but EPA is not aware of any data that is available to quantify the additional reduction attributable to snow. We do not believe that we could develop an additional correction term to account for snow, but a reasonable approach would be to assume zero emissions during periods when the road surface is covered with snow. Note, however, that the application of traction materials following a snow event has the effect of significantly increasing silt loading resulting in increased emissions.

Dr. Countess commented that there is a residual effect of moisture that lasts beyond the precipitation event and would result in reduced emissions for some period after precipitation stops. EPA agrees with this concept and has addressed it in the hourly moisture correction term. Dr. Countess further commented that there should be some consideration for the amount of precipitation that occurs during an event and that the EPA proposed correction terms do not take this in to account. Dr. Countess expanded on this point by developing a comparison with the application rate of chemical dust suppressants on unpaved roads and asserting that there should be some consistency in estimating the influence of moisture in reducing emissions from both paved and unpaved roads. EPA agrees that in concept this is almost certainly the case. However, we have proposed these correction terms with no measured emissions data to quantify the emissions reductions. Our assumption is that when measurable precipitation (greater than 0.01 inches during a period) occurs, that emissions are zero during the precipitation event. Until data are available that will allow us to quantify the effect of the magnitude of precipitation, EPA will limit the correction term to the on/off approach defined by the 0.01 inch trigger.

Dr. Countess commented that the way EPA accounts for vehicle weight is flawed. He advocates for an approach that would estimate emissions by vehicle weight class then add these emissions rather than the EPA approach which uses an average weight for all of the vehicles traveling on a road. The great majority of the test data that EPA uses to develop the emission factor equations come from tests on public roads where it is not possible to control the distribution of vehicles that traverse the tested road segment. Our regression analysis shows vehicle weight to have a high correlation coefficient. Since it is not possible to determine the emissions from each vehicle during a test, we are limited to using the average weight of all of the vehicles for each test.

Ms. Michelle Chang commented that she favored the selection of Option 1 (Daily Moisture Correction) over Option 2 because PM10 increment modeling is based on a 24 hour average. EPA will allow the use of either option in the final version.

Ms. Evelyn Schulze commented that some German work had shown that the proportion of exhaust pipe emissions to other emissions was about 50:50. She suggested that the AP-42 method should account for the difference in the release mechanism between exhaust emissions and other emissions. EPA agrees that this is likely the case. However, we are limited by the constraints of the test data that do not permit the separation of the exhaust component from the total fugitive emissions. EPA's MOBILE6.1 emissions model includes the particulate matter exhaust component. We are evaluating the possibility of using the MOBILE6 capability to address this issue in a future revision.

As the use of MOBILE6.1 increases, users are cautioned to avoid double counting of the PM components calculated by the MOBILE6.1 model. This is particularly important on high traffic density, low silt loading roads where the emissions from the tailpipe can be a significant portion of total roadway emissions.

Based on these comments, EPA is revising AP-42, Section 13.2.1, Paved Roads, by adding two new equations that account for the mitigative effect of precipitation on long term emissions. Equation 2 applies a correction term on a daily basis, Equation 3 on an hourly basis. The equations are:

Daily Basis:

$$E_{ext} = k\,(sL/2)^{0.65}\,(W/3\,)^{1.5}\,(1-P/4N) \qquad (2)$$

where:

E_{ext} = annual or other long-term average emission factor in the same units as k
k = base emission factor for particle size range and units of interest (see below)
sL = road surface silt loading (grams per square meter) (g/m^2)
W = average weight (tons) of the vehicles traveling the road
P = number of "wet" days with at least 0.254 mm (0.01 in) of precipitation during the averaging period
N = number of days in the averaging period (e.g., 365 for annual, 91 for seasonal, 30 for monthly)

Hourly Basis:

$$E_{ext} = k\ (sL/2)^{0.65}\ (W/3\ )^{1.5}\ (1\text{-}1.2P/N) \qquad (3)$$

where:

E_{ext} = annual or other long-term average emission factor in the same units as k
k = base emission factor for particle size range and units of interest (see below)
sL = road surface silt loading (grams per square meter) (g/m^2)
W = average weight (tons) of the vehicles traveling the road
P = number of hours with at least 0.254 mm (0.01 in) of precipitation during the averaging period
N = number of hours in the averaging period (e.g., 8760 for annual, 2124 for seasonal, 720 for monthly)

Note: In the hourly moisture correction term (1-1.2P/N), the 1.2 multiplier is applied to account for the residual mitigative effect of moisture. For most applications, this equation will produce satisfactory results. However, if the time interval for which the equation is applied is short, e.g., for one hour or one day, the application of this multiplier makes it possible for the moisture correction term to become negative. This will result in calculated negative emissions which is not realistic. Users should expand the time interval to include sufficient "dry" hours such that negative emissions are not calculated. For the special case where this equation is used to calculate emissions on an hour by hour basis, such as would be done in some emissions modeling situations, the moisture correction term should be modified so that the moisture correction "credit" is applied to the first hours following cessation of precipitation. In this special case, it is suggested that this 20% "credit" be applied on a basis of one hour credit for each hour of precipitation up to a maximum of 12 hours.

List of Comments Received:

Note: Interested parties may review the complete comments which are available in pdf format.

Michelle Chang, email dated November 28, 2001

Richard J. Countess, letter dated November 21, 2001

Ronald E. Myers, letter dated November 30, 2001

Evelyn Schultze, email dated November 27, 2001

Bill Kuykendal

05/08/02 04:28 PM

To: Ron Myers/RTP/USEPA/US@EPA, Tom Pace/RTP/USEPA/US@EPA
cc: Phil Lorang/RTP/USEPA/US@EPA
Subject: comment2

#2
----- Forwarded by Bill Kuykendal/RTP/USEPA/US on 05/08/02 04:29 PM -----

LOHMEYER_DD@t-online.de (Ingenieurbüro Lohmeyer)

11/27/01 05:15 AM
Please respond to info.dd

To: Bill Kuykendal/RTP/USEPA/US@EPA
cc:
Subject: comment2

Dear Mr. Kuykendal,

referring to my questions from the 15th of November I'd like to add some ideas about PM10-emission-calculaions used in German projects. A file of the summary "Determination of 'non-exhaust-pipe' PM10 emissions of roads for practical traffic air pollution modelling" is enclosed. It contains issues about the modification of the EPA formula and some background information.

Maybe it could be interesting for you to note that in those projects it was distinguished between PM emissions from exhaust pipes and PM emissions due to resuspension and abrasion on the street itself.
It was recognized that on ordinary streets the proportion of exhaust pipe emission to other emission is about 50:50.
I think this is important regarding possible PM10-reductions due to precipitation if we consider independancy of exhaust pipe emissions to precipitation.

Best regards,

Evelyn Schulze

Ingenieurbüro Dr.-Ing. Achim Lohmeyer
Mohrenstr. 14
01445 Radebeul
Tel.:0351-83914-0
Fax.:0351-83914-59
e-mail: info.dd@lohmeyer.de
Homepage: www.lohmeyer.de

Summary PM10 Saxony Berlin Ve

Determination of the "non exhaust pipe" PM10 emissions of roads for practical traffic air pollution modelling.

First draft, dated 21.9.2001

English summary of a report, dated June 2001, initiated and financed by Sächsisches Landesamt für Umwelt und Geologie, Radebeul and Senatsverwaltung für Stadtentwicklung, Berlin, prepared by Ingenieurbüro Dr.-Ing Achim Lohmeyer, Radebeul

Aim of the project

EC Council Directive 1999/30/EC sets a limit for the concentration of PM10 in the ambient air. Field measurements show an exceedance of this limit in the vicinity of roads (Lenschow et al., 2001), thus the problem has to be addressed and the reasons for the exceedances detected. However, PM10 pollution modelling in the vicinity of a paved road is deficient because the determination of the PM10 emissions is vague. For the vehicle fleet in Germany, there is comparatively good information on the contribution coming out of the exhaust pipe, but the quantification of the PM10 emissions resulting from abrasion of vehicle components and especially from the road surface is not satisfactorily solved.

Therefore a project was launched to proceed in the non exhaust pipe PM10 emission modelling in Germany. The modelling should be applicable for operational purposes by state and city authorities and consultants and it should be based on easily available input parameters. The project consisted of the following steps:

- Literature survey for identification of an available model
- Field measurements in a heavily trafficked street canyon in Leipzig and in Berlin to check the performance of the model
- First proposal for possible modifications of the model to improve its performance for use in Germany

Results of the project

a) Literature survey

The only operational models were found to be a model in Sweden (SMHI-model, Bringfeld et al., 1997) and the model of the US-EPA (EPA, 1997). For the EPA model, Rauterberg-Wulff (2000) showed, how it needed to be modified in order to describe the results of field measurements in Frankfurter Allee, Berlin. Landesumweltamt Brandenburg (LUA, 2000) modified it for the application in the State of Brandenburg.

Other countries for example Austria, UK, France determine the PM10 emissions of roads from the exhaust pipe emissions of NO_x, soot or particles.

The survey shows a large uncertainty concerning the PM10 emission of roads by dust re-suspension and abrasion. Much complaints about the lack of a decent model can be found. The performance of the EPA model is considered not to be suitable by an expert group in the US (Venkatram, 2000), and the UK Airborne Particle Expert Group (APEG, 1999) considers the model not to be applicable in the UK.

Nevertheless, as an operational model has to be provided to meet the EC Directives and as there is presently nothing else than the EPA model, this model was used as the basis for the project. The latest EPA version is

$$e = 0.56(sL)^{0.65}(W)^{1.5}$$

where sL is the silt load (PM75) in g/m^2, W is the average weight of the vehicle fleet in tons and e is the PM_{10} emission in g/VKT for days without rain, where VKT means Vehicle Kilometre Travelled.

The calculated emission contains all contributions, i.e. exhaust pipe emissions plus emissions by re-suspension and abrasion. No emission is supposed to occur during days with rain.

For most PM10 emission data, found in the literature, it could be derived, that the total PM10 emission in g/VKT of these roads was 2 to 4 times the exhaust pipe PM emission.

b) Field Measurements in Leipzig

From mid October to mid November 2000, field measurements in the street canyon Lützner Strasse in Leipzig were done, including determination of the silt load of the street, traffic counts (passenger cars and trucks), PM10 and PM2.5 concentrations including analysis of the PM components and PM10 and PM2.5 background concentrations. The findings are:

The PM75 silt load of the street (needed for the application of the EPA model) was 0.16 to 0.25 g/m^2 on the traffic lanes, 1.6 to 2 g/m^2 in 0 to 25 cm distance from the curb, leading to a mean (area weighted) load of 0.38$\pm$0.21 g/m^2. This value is about double the value, found by Rauterberg-Wulff (2000) in Berlin, Frankfurter Allee.

In spite of the short period of the measurements and unfavourable wind conditions, the total PM10 emissions, determined by inverse dispersion modelling (0.47 to 1.1 g/VKT), are higher than calculated by the EPA formula (0.37 to 0.84 g/VKT, depending on the silt load applied). On the basis of the German Exhaust Pipe Emission Factor Handbook (INFRAS, 1999), an emission of 0.056 g/VKT is determined, thus the non exhaust pipe contribution is 0.55 to 0.65 g/VKT. So, in this street for that time period, there was roughly a factor of 10 between emission by re-suspension/abrasion and exhaust pipe.

This high emission by re-suspension/abrasion could be caused by the bad condition of the road surface, being very old and cracked, additionally by the heavily silt loaded pedestrian walkways and the unpaved parking spaces parallel to the road.

c) Field Measurements in Berlin

From mid November to mid December 2000, field measurements in the street canyon Schildhornstrasse in Berlin were done, including determination of the silt load of the street, traffic counts (passenger cars and trucks), PM10, PM2.5 and NO_x concentrations at the street and in the background including analysis of the PM components at all monitoring stations. The findings are:

The PM75 silt load of the street was 0.06 to 0.14 g/m^2 on the traffic lanes, 1.7 to 2.3 g/m^2 in 0 to 25 cm distance from the curb, leading to a mean load of 0.16$\pm$0.09 g/m^2. This value is nearly the same as found by Rauterberg-Wulff (2000) in Berlin, Frankfurter Allee with ca. 0.2 g/m^2. The components of the silt load were found to be ca. 86 % mineral components, ca. 4 % EC and ca. 2.8 % OC, all percentages being nearly independent from their position on the road.

As the PM10 component analysis of the PM10 concentrations was done for the measurements at the street and in the background, the additional street concentration could be determined to be 52 % consisting of mineral components (mostly re-suspension and abrasion), 7 % tire wear and 41 % exhaust pipe emission.

By inverse dispersion modelling, the total PM10 emission factor of the road could be determined to be 0.091 to 0.096 g/VKT.

By an alternative, less effort consuming method, using NO_x as a tracer (without dispersion modelling but using the NO_x emissions and the NO_x additional street concentrations) 0.081 to 0.095 g/VKT were found. Thus it was shown, that the 2 methods yielded nearly the same result in this case.

The total PM10 emissions, determined by inverse dispersion modelling (0.091 to 0.096 g/VKT), are lower than calculated by the EPA formula (0.19 to 0.45 g/VKT, depending on the silt load applied).

On the basis of the German Exhaust Pipe Emission Factor Handbook (INFRAS, 1999), an emission of 0.045 g/VKT is determined. Thus the non exhaust pipe contribution in this street for that time period, was roughly the same as the exhaust pipe emission.

By separate analysis of the results during working days and weekends, a separate estimation of the emission factors for trucks and for passenger cars could be done.

The problem of the modification of the emission factors by rain is addressed.

d) Modified model

On the basis of measurements in Switzerland and Germany, a first modification of the EPA model was done, dividing in a first step into exhaust pipe emissions and the contributions by resuspension and abrasion as

$$e = e_{exhaust\ pipe} + e_{road\ abrasion+re-suspension}$$

The exhaust pipe contribution is taken from the German Exhaust Pipe Emission Factor Handbook (1999). Thus it is depending on the year under consideration, in contrary to the contribution by road abrasion and re-suspension.

The road abrasion and re-suspension contribution is considered to be depending on the silt load, the average weight of the vehicle fleet and the number of rainy days. Default parameters for city streets, streets in the open country and motorways are given in the report. A completely separate model is given for the emissions of tunnels.

As the model is mostly based on the EPA model, it still contains its problems.

Open tasks

At this moment, although we do not have enough data, we propose to discuss a model with the following input parameters:

- Composition of the road surface (as, for example, asphalt has a larger abrasion than concrete)
- State of the road (new, old, porous, smooth, rough, patched, cracked, weather beaten etc.)
- Driving pattern, vehicle speed, ADT, truck content, etc
- Amount of dirt deposited from outside sources
- Local conditions of rain and humidity

More theoretical work is needed as well as communication input from road maintaining civil engineers. More experiments have to be designed to determine the relevance of the above-mentioned parameters and also to find new possible parameters governing PM_{10} emission.

Ongoing and future projects

Presently the following projects are going on or will go on.

In September 2001, Senatsverwaltung für Stadtentwicklung, Berlin started a measurement campaign, exceeding the measuring period to 1 year and additional monitoring positions.

Niedersächsisches Landesamt für Ökologie, Hannover, will add to the 3 year measurements for VALIUM sophisticated sophisticated measurements of the PMx street canyon and background concentrations to do a source apportionment for PM10 concentration hot spots.

BWPLUS will finance from beginning 2002 to mid 2003 a program to collect the results of all PM10 concentrations measured routinely by the German States near roads and to evaluate them for the local PM10 emission factors. Additionally it will finance a detailed study at a street including windward/leeward concentration measurements, rain, wind, traffic etc. in high temporal resolution.

Bibliography

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Bringfelt, B., Backström, H., Kindell, S., Omstedt, G., Persson, C., Ullerstig, A. (1997): Calculations of PM10 concentrations in Swedish cities - Modelling of inhalable particles. Published by Swedish Meteorological and Hydrological Institute, Norrköping, Sweden (Report number RMK No. 76).

INFRAS (1999): INFRAS im Auftrag des UBA, Berlin: "Handbuch Emissionsfaktoren des Straßenverkehrs", Version 1.2, Januar 1999.

Lenschow, P, H.J. Abraham, K. Kutzner, M. Lutz, J.-D. Preuß and W. Reichenbächer (2001): Some Ideas about the Sources of PM10. In: Atmospheric Environment 35 Supplement No. 1 (2001) S23 – S33.

LUA (2000). Vorgehensweise bei der Schwebstaubimmissionsberechnung nach Richtlinie 1999/30/EG. Entwurf des Referats I3 vom 21.12.2000, Landesumweltamt Brandenburg.

Rauterberg-Wulff, A. (2000): Untersuchung über die Bedeutung der Staubaufwirbelung für die PM10-Immission an einer Hauptverkehrsstraße. Techn. Univ. Berlin, Fachgebiet Luftreinhaltung (Januar 2000).

US-EPA (1997): AP-42, 5. Edition, Volume 1, Chapter 13, Section 13.2.1. Miscellaneous sources.

Venkatram, A. (2000): A critique of empirical emission factor models: a case study of the AP-42 model for estimating PM10 emissions from paved roads. Atmosph. Envir. 34, 1-11.

Availability of report

The report can be downloaded from www.Lohmeyer.de/Literatur/zusammenfassung_06_01.pdf. It is in German.

Ronald E. Myers
1625 Westhaven Dr.
Raleigh, NC 27607

November 30, 2001

Mr. Bill Kuykendal
U.S. EPA
Research Triangle Park, NC 27711

Dear Mr. Kuykendal:

I have read the revisions that are being proposed for the paved and unpaved roads sections of AP-42. First, there is little information presented to support any of the options being proposed. For example, for the paved road proposal, there is no information to characterize the physical mechanisms which cause the precipitation related mitigation of emissions and no subsequent evaluation was performed to compare (based upon the physical mechanisms) the two options using the results of calculations from daily information and hourly information. For the unpaved road proposal, the individual test results upon which the data presented in Figure 1 are derived is not summarized as has been done for the background report which is being supplemented and has been presented in all other AP-42 background reports. While the data presented in Figure 1 for the surface coal mine may already be summarized in the existing background report, there is no information in the memo from Greg Muleski of MRI to you on how the data were manipulated to accommodate the differences in silt content and vehicle weight between test runs to arrive at emission factors which can be used to arrive at a control efficiency which is independent of silt and average vehicle weight. In addition, for the unpaved road options, no information is presented which compares the emissions that would be predicted using the watering control effectiveness figure to the actual measured emissions from the over 100 emission tests that are presented in the existing background report supporting the emission factors you are proposing to replace. To provide some of these comparisons, I have obtained some data to use for evaluation.

PAVED ROAD PROPOSAL

The two options presented could be assumed to infer that precipitation completely suppresses emissions for either half of the day that rain occurs or only for the hour that rain occurs. Based upon information for 1990 contained in the *Solar and Meteorological Surface Observation Network 1961-1990* (SAMSON) CD-ROM, I calculated information to compare the two options for some selected cities. The cities range from having only 20 rain days per year to having 157 rain days per year. Information on the attached material includes the monthly number of rain days, the number of hours that rain was measured, the percent reduction for both of the options and the percent difference in the two options. As you may notice, on average rain occurs for only 20% of the day and ranges from 8% for Elko, NV to 37% for Olympia, WA. On average, using the daily calculation option results in almost three times the emission reduction of the hourly calculation. This difference ranges from 1.35 for Olympia to 6.25 for Winnemucca. For these two options to be comparable, the average emissions reduction would have to be two to three times the average percentage of the day that rain was measured.

In extracting this data, it appeared that most rain events were of short duration (measured values during only one or two consecutive hours) although there were a few periods for most cities where measured rain occurred for most if not all of the day. While no measured data is available to evaluate the two options, it is reasonable to expect that the following situations affect the ability of precipitation to mitigate emissions:

1) Light precipitation increases the availability of silt for suspension into the air as a result of the washing of material out of crevices of the road. While the road surface is wet, water droplets suspended into the air will contain these suspended solids and if not deposited, will become airborne particulate emissions.

2) Light precipitation can increase silt levels as a result of the washing action of water on the undercarriage of vehicles.

3) The timing of short duration rain events affects the reduction of silt during high traffic periods. Rain occurring late in the evening or at night is unlikely to significantly affect silt levels during high traffic periods since the undercarriage of the first vehicles to use the road will re-nourish the road surface due to the washing by the residual water on the road surfaces.

4) Any precipitation can increase silt levels as a result of enhancing the track out of material from unpaved areas such as construction sites, unpaved roads, quarries and other industrial locations.

5) Heavy precipitation will remove most silt from the road surface. This effect will last the longest when rain occurs during rush hours.

6) Paved roads are designed to minimize the amount of water retained on the surface.

7) Normally, high speed and volume roadways will dry within an hour after rain has ceased.

8) Low humidity, high temperature and high solar insolation conditions will reduce drying times of a road.

For light rains of short duration, which appeared to be the most prevalent, it is assumed that the times where silt content would be increased are balanced by the times where the amount of rain is sufficient to reduce the silt content of the road. As a result, emissions are suppressed only during the period when it is raining. Since the meteorological data is recorded in one hour blocks, it may be reasonable to assume that emissions are suppressed for the entire hour.

Rains which are somewhat more intense or longer duration can remove imbedded silt from the road surface. These type events have a 18% probability (10 x 3/24 x 7 = .18, for commute periods of 3 hours) of removing the majority of the silt from the traffic system. If it is assumed that silt levels increase linearly and it takes forty three hours for silt levels to return to the normal levels during this type of event, and that the rain was of average duration (.2 x 24 = 4.8 hr), this would be equivalent to a 55% suppression of emissions for two days ((0 x 4.8 + 0.5 x 43 x 1)/48 = 0.45). For the remaining 82% of the time, emissions would be suppressed for only the 4.8 hours when it was raining (and also during lower traffic flow) for an average of 20% suppression of emissions. On average, the resulting emissions would be reduced 26% (.55 x .18 + .82 x .2 = .26) or the equivalent of 1.32 times the amount if emissions were assumed to be zero only during the 5 hours of recorded rain.

For long duration rains (say of one or 2 days duration), silt levels would require 36 hours to return to normal levels as above. As a result, emissions would be suppressed for two days plus the duration for silt levels to return to normal. For a one day rain, emissions over a three day period (one day of rain plus two days to recover) would be reduces by 66% or 2 times the amount if emissions were assumed to be zero only during the 24 hours of recorded rain. Emissions over a four day period (two days of rain plus two days to recover) would be reduced by 75% or 1.5 times the amount if emission were assumed to be zero only during the 48 hours of recorded rain.

As can be seen, for the two options to be comparable, all of the rains would have to last all day and silt levels would require more than two days to return to normal levels. For the more typical climate, a mixture of these type events is likely. Based upon my observations, I would think that the first type event would occur more than half the time, while the third type event would only occur less than 10% of the time. For illustration, it is assumed that the first type event occurs 60% of the time, the second type event occurs 30% of the time and the third type event occurs 10% of the time. Based upon these assumptions, the number of hours of rain would need to be multiplied by 1.2 to estimate the residual mitigation of rain
(1 x 0.6 + 1.3 x 0.3 + 2 x 0.1 = 1.19)

It is recognized that calculating the mitigating effect of precipitation using the number of days with measurable precipitation may be simpler than obtaining and calculating the mitigation using hourly data. As a result, to provide users with a method to calculate mitigation from daily precipitation data, it is suggested that rather than using the following equation:

$$E_{ext} = k\,(sL/2)^{0.65}\,(W/3)^{1.5}\,(1-P/4N)$$

It is also recommended that the use of hourly data be optional using the following equation:

$$E_{ext} = k\,(sL/2)^{0.65}\,(W/3)^{1.5}\,(1-1.2P/N)$$

UN-PAVED ROAD PROPOSAL

While I can understand the desire to have separate emission factors for urban and industrial roads even though the basic parameters are nearly the same, it is contrary to good scientific principals to use a limited data set to isolate a parameter and to ignore a larger data set that includes parameters that address many if not all the variables which affect the overall effect. Although some AP-42 readers may incorrectly and unsuccessfully attempt to isolate the effect of watering to increase surface moisture content, this can be corrected using an explanation in the text of the section to highlight the inter-relatedness of the effects caused by watering and proper maintenance of an industrial unpaved road surface. While, a revised industrial unpaved road equation may only have an exponent of about 0.4 to estimate the effects of moisture content on emissions, the exponent is an accurate reflection based upon all of the available data.

Within the context of using the bi-linear control performance model from EPA-450/3-88-08, there is no limitation on the maximum baseline moisture content that is applicable when using this model. It has is recommended that the range of baseline moisture contents be presented for AP-42 readers to understand the potential limitations of this model. It is also recommended that the individual baseline and controlled data that are represented by the approximately 38 points in the figure be presented in the revised memo (or supplement to the background report) so that users may access this information should they want to better understand the available data. In presenting this data, information on the silt content, average weight, vehicle speed and number of tires be included in the data summaries. It is also suggested that data from the existing background data (other than the coal mine data) be added to the existing figure so that a more comprehensive characterization of the quality of the models performance can be discerned. The entire data set used for the previous version of the unpaved road equation was evaluated to identify groups of data where the vehicle weight and the silt content were nearly the same. Nineteen groups of data were identified and the moisture ratio and control efficiency were calculated. Attached is the complete ordered data set with the nineteen data sets identified. On the last page of this attachment is a figure that presents the predicted control efficiency and the actual control efficiency for these nineteen pairs of data. Within these nineteen data, there were five which had negative control efficiencies due to the higher moisture level condition having higher emissions than the condition to which it was compared. It is suggested that additional pairs of data be identified within this data set and the basis of the model be re-evaluated and revised to agree with the data.

I hope these comments are helpful. Should you require any clarification in my comments or the attachments I am providing, please contact me at (919) 851-1564.

Sincerely,

Ronald E. Myers

Estimate of Paved Road Emissions Reduction due to rain events

		January	February	March	April	May	June	July	August	September	October	November	December	Annual
Olympia, WA	Rain Days	25	20	16	14	14	13	4	7	1	20	26	23	157
	Estimated Reduction per EIP	40%	36%	26%	23%	23%	22%	6%	11%	2%	32%	43%	37%	22%
	Rain Hours	230	214	133	110	59	74	14	30	2	137	226	166	1395
	Estimated Reduction	31%	32%	18%	15%	8%	10%	2%	4%	0.3%	18%	31%	22%	16%
	Percent Difference from EIP	23%	11%	31%	35%	65%	53%	71%	64%	83%	43%	28%	40%	26%
Harrisburg, PA	Rain Days	12	13	10	16	16	7	10	11	12	7	8	14	128
	Estimated Reduction per EIP	19%	23%	16%	27%	26%	12%	16%	18%	20%	11%	13%	23%	18%
	Rain Hours	82	66	59	64	91	16	50	98	43	60	36	109	774
	Estimated Reduction	11%	10%	8%	9%	12%	2%	7%	13%	6%	8%	5%	15%	9%
	Percent Difference from EIP	43%	58%	51%	67%	53%	81%	58%	26%	70%	29%	63%	35%	50%
Albany, NY	Rain Days	16	12	9	12	15	12	8	11	10	7	9	12	124
	Estimated Reduction per EIP	26%	21%	15%	20%	24%	20%	13%	18%	17%	11%	15%	19%	17%
	Rain Hours	93	94	63	77	112	27	31	88	29	46	46	78	784
	Estimated Reduction	13%	14%	8%	11%	15%	4%	4%	12%	4%	6%	6%	10%	9%
	Percent Difference from EIP	52%	35%	42%	47%	38%	81%	68%	33%	76%	45%	57%	46%	47%
Raleigh, NC	Rain Days	10	10	9	12	15	5	8	12	4	9	6	15	115
	Estimated Reduction per EIP	16%	18%	15%	20%	24%	8%	13%	19%	7%	15%	10%	24%	16%
	Rain Hours	68	43	61	30	65	10	18	35	9	46	25	74	484
	Estimated Reduction	9%	6%	8%	4%	9%	1%	2%	5%	1%	6%	3%	10%	6%
	Percent Difference from EIP	43%	64%	44%	79%	64%	83%	81%	76%	81%	57%	65%	59%	65%
Springfield, IL	Rain Days	9	11	12	10	14	14	7	8	6	8	7	13	112
	Estimated Reduction per EIP	15%	20%	19%	17%	23%	23%	11%	13%	10%	13%	12%	21%	15%
	Rain Hours	35	79	51	43	76	46	30	32	31	62	46	101	632
	Estimated Reduction	5%	12%	7%	6%	10%	6%	4%	4%	4%	8%	6%	14%	7%
	Percent Difference from EIP	68%	40%	65%	64%	55%	73%	64%	67%	57%	35%	45%	35%	53%
Spokane, WA	Rain Days	18	11	7	10	17	8	5	4	0	11	11	10	101
	Estimated Reduction per EIP	29%	20%	11%	17%	27%	13%	8%	6%	0%	18%	18%	16%	14%
	Rain Hours	94	48	29	53	79	40	29	16	0	75	38	63	564
	Estimated Reduction	13%	7%	4%	7%	11%	6%	4%	2%	0%	10%	5%	8%	6%
	Percent Difference from EIP	56%	64%	65%	56%	61%	58%	52%	67%	ERR	43%	71%	48%	53%
Oklahoma City, OK	Rain Days	3	9	14	14	10	4	7	8	9	5	5	9	92
	Estimated Reduction per EIP	5%	16%	23%	23%	16%	7%	11%	13%	15%	8%	8%	15%	13%
	Rain Hours	26	69	79	62	48	12	22	21	33	19	33	40	464
	Estimated Reduction	3%	10%	11%	9%	6%	2%	3%	3%	5%	3%	5%	5%	5%
	Percent Difference from EIP	28%	36%	53%	63%	60%	75%	74%	78%	69%	68%	45%	63%	58%

Estimate of Paved Road Emissions Reduction due to rain events

		January	February	March	April	May	June	July	August	September	October	November	December	Annual
Houston, TX	Rain Days	14	11	10	9	5	4	10	1	10	4	7	9	87
	Estimated Reduction per EIP	23%	20%	16%	15%	8%	7%	16%	2%	17%	6%	12%	15%	12%
	Rain Hours	103	48	43	31	15	8	26	1	26	20	28	35	384
	Estimated Reduction	14%	7%	6%	4%	2%	1%	3%	0%	4%	3%	4%	5%	4%
	Percent Difference from EIP	39%	64%	64%	71%	75%	83%	78%	92%	78%	58%	67%	68%	63%
Birmingham, AL	Rain Days	12	13	11	9	8	5	0	0	0	7	3	11	76
	Estimated Reduction per EIP	19%	23%	18%	15%	13%	8%	0%	0%	0%	11%	5%	18%	10%
	Rain Hours	109	66	83	29	34	15	0	0	0	17	18	33	404
	Estimated Reduction	15%	10%	11%	4%	5%	2%	0%	0%	0%	2%	3%	4%	5%
	Percent Difference from EIP	24%	58%	37%	73%	65%	75%	ERR	ERR	ERR	80%	50%	75%	56%
Winnemucca, NV	Rain Days	12	13	11	9	8	5	0	0	0	7	3	11	76
	Estimated Reduction per EIP	19%	23%	18%	15%	13%	8%	0%	0%	0%	11%	5%	18%	10%
	Rain Hours	16	25	21	34	45	5	0	19	6	5	7	26	209
	Estimated Reduction	2.2%	3.7%	2.8%	4.7%	6.0%	0.7%	0.0%	2.6%	0.8%	0.7%	1.0%	3.5%	2.4%
	Percent Difference from EIP	89%	84%	84%	69%	53%	92%	ERR	ERR	ERR	94%	81%	80%	77%
Elko, NV	Rain Days	3	2	5	8	6	3	2	3	1	1	4	0	34
	Estimated Reduction per EIP	5%	4%	8%	13%	10%	5%	3%	5%	2%	2%	7%	0%	5%
	Rain Hours	8	2	9	16	9	7	2	6	1	1	9	0	70
	Estimated Reduction	1.1%	0.3%	1.2%	2.2%	1.2%	1.0%	0.3%	0.8%	0.1%	0.1%	1.3%	0.0%	0.8%
	Percent Difference from EIP	78%	92%	85%	83%	88%	81%	92%	83%	92%	92%	81%	ERR	83%
Las Vegas, NV	Rain Days	5	4	0	1	0	2	4	0	3	1	2	0	20
	Estimated Reduction per EIP	8%	7%	0%	2%	0%	3%	6%	0%	5%	2%	3%	0%	3%
	Rain Hours	25	14	0	2	0	8	10	0	7	3	3	0	72
	Estimated Reduction	3.4%	2.1%	0.0%	0.3%	0.0%	1.1%	1.3%	0.0%	1.0%	0.4%	0.4%	0.0%	0.8%
	Percent Difference from EIP	58%	71%	ERR	83%	ERR	67%	79%	ERR	81%	75%	88%	ERR	70%

Annual Avg using Daily Data	Ave	12.8%
	Std	5.3%
	Min	2.7%
	Max	21.5%

Annual Avg using Hourly Data	Ave	5.9%
	Std	4.1%
	Min	0.8%
	Max	15.9%

Differences between Hourly and Daily Data	Ave	58.4%
	Std	15.0%
	Min	25.9%
	Max	82.8%

November 21, 2001

Bill:

I am submitting the following comments for your evaluation in response to your request for comments on the draft sections of AP-42 that address paved and unpaved roads.

Section 13.2.1 "Paved Roads"

I certainly endorse the addition of a "precipitation correction term" to the emission factor equation. Should equation 2 state that one is dealing with precipitation in the form of rain? Since snow will have a different effect than rain on mitigating dust emissions, shouldn't this be addressed, especially if the temperature is below freezing such that the snow remains on the roadway and is a physical barrier to road dust resuspension?

Without actual data showing the effect of precipitation on paved road emissions, either option has its merits. I believe that Option 1 (i.e., making an adjustment on a daily basis) is superior to Option 2 (i.e., making an adjustment on an hourly basis) from the stand point that the amount of precipitation that occurs in the period following the initial precipitation will have a cumulative effect on increasing the moisture content of the surface road dust, and consequently decrease the probability of dust emissions. However, I disagree with the amount of precipitation being proposed that would effectively reduce dust emissions to zero (see my comments below). On the other hand, Option 2 has a nice simplicity to it in that it allows one to set the emissions to zero for that single hour. Whatever option is selected, there should be a provision that addresses a reduction in emissions in subsequent time periods following a precipitation event (i.e., next day, or next several hours) that is dependent on the total amount of precipitation.

As I interpret equation 2 (Option 1), this equation states that paved road dust emissions on days with at least 0.01" precipitation are only half that of days with less than 0.01" precipitation. However, I don't see any scientific documentation for the incorporation of a factor of "2" in the precipitation correction term for paved roads. It appears to more of a "WAG" than a sound scientific fact. Furthermore, whether one accepts for the moment the assumption that precipitation of at least 0.01" per day will reduce paved road dust emissions to zero (a claim that I address below), it is inconsistent to set different threshold values for zero emissions for both options being considered, namely 0.01"/day for Option 1 and 0.01"/hour for Option 2. If 0.01"/hour is the correct value for Option 2, then shouldn't one be using a value of 0.24"/day for Option 1?

There should be consistency between the models used for paved roads and those used for unpaved roads for evaluating the effect of precipitation. Figure 13.2.2-5 indicates that the control efficiency for fugitive dust emissions from unpaved roads is assumed to be zero for a ground inventory of less than 0.05 gallons of petroleum resin applied per square yard if the time between applications is 2 weeks to 1 month. Unfortunately, this figure doesn't show what the control efficiency would be if the time between applications were a day let alone one hour. Assuming for a moment that water has an equivalent effect on mitigating dust as petroleum resin at least in the short term, precipitation amounting to 0.01" per hour, which is equivalent to 0.056 gallons/square yard, will have a negligible effect on controlling fugitive dust emissions from unpaved roads, and by extension, from paved roads. In fact, according to the data presented in Figure 13.2.2-5, it will require 0.25 gallons of petroleum resin per square yard applied at intervals of 2 weeks to one month to reduce dust emissions by 80%. Again, assuming that water will have an equivalent effect on mitigating dust as petroleum resin at least in the short term, precipitation of 0.25 gallons/square yard per hour is equivalent to 0.045"/hour or 1.08"/day. The bottom line is that I don't see any evidence or documentation that 0.01" of precipitation per hour, let alone 0.01"/day, will reduce fugitive dust emissions to zero.

I believe that using a mean vehicle weight (W) for cars and trucks for calculating PM emissions from paved roads has a major logical flaw. Logically it makes more sense to look at the sum of all the sources contributing to the total emission rate. In fact this is the practice recommended by the South Coast AQMD. To illustrate the fallacy of averaging the weight of all vehicles on the road, consider the simple case where there is one car weighing 3 tons and one loaded truck weighing 39 tons. Using the average weight of these two vehicles in the emission factor equation for paved road dust results in a PM10 emission rate of 0.1225 lbs/mile per vehicle, or 0.243 lbs/mile for both vehicles. Calculating the emission rate for the car and the truck separately and adding the two terms results in a total PM10 emission rate of 0.314 lbs/mile with 0.307 lbs/mile contributed by the truck. By averaging the vehicle weights, the total emission rate is less than that of the truck by itself. Obviously, averaging the vehicle weights does not give an accurate account of the true situation. (Note: my estimates of PM10 emission rates were taken from emission factors published by the South Coast AQMD.)

Section 13.2.2 "Unpaved Roads"

I am certainly happy to see that the new equations for public unpaved roads include a speed correction term. My review of Sehmel's original field test results (Atmos. Environ, 1973) for public unpaved roads indicate that TSP emissions from light duty passenger cars appear to increase with speed to the second power for speeds of 30 mph or lower and appear to increase with speed to the first power for speeds over 30 mph. Sehmel did not measure PM10. I would like to suggest that the EPA consider two speed regimes for estimating PM emissions from public unpaved roads: (a) $\leq$ 30 mph, and (b) greater than 30 mph.

Furthermore, Sehmel's original field data for a ¾ ton truck indicates that TSP emissions are proportional to speed to the 0.4 power. Perhaps, you need an option to calculate the PM emissions separately from light duty cars and from trucks. Again, as I discussed above, I believe that using a mean vehicle weight (W) for cars and trucks for calculating PM emissions from unpaved industrial roads is flawed.

Since the PM emissions data of Roberts et al (J.APCA, 1975) for a car traveling on a gravel road indicated that the PM10/TSP ratio increases with increasing speed, the new emission factor equations for unpaved roads should account for this fact. My review of the original field results indicate that for speeds up to 30 mph the TSP emissions increase as a function of speed to the 1.7 power, whereas the PM10 emissions increase as a function of speed to the 2.65 power.

The R-squared values for the proposed emission factor models for PM10 reported in Greg Muleski's September 27th memo to you (see Table 1) would be considered low by most individual's standards. Hopefully, adopting one or more of my suggestions will improve the R-squared values, and thus the accuracy of the fugitive dust emission prediction equations.

Please contact me if you have any questions regarding my comments.

Sincerely,

Richard J. Countess, Ph.D.
COUNTESS ENVIRONMENTAL

Bill Kuykendal

05/08/02 04:30 PM

To: Ron Myers/RTP/USEPA/US@EPA, Tom Pace/RTP/USEPA/US@EPA
cc: Phil Lorang/RTP/USEPA/US@EPA
Subject: Road Silt Draft

#4

----- Forwarded by Bill Kuykendal/RTP/USEPA/US on 05/08/02 04:31 PM -----

Michelle_Chang@cargill.com

11/28/01 05:06 PM

To: Bill Kuykendal/RTP/USEPA/US@EPA
cc:
Subject: Road Silt Draft

In section 13.2.1.3 titled Predictive Emission Factor Equations (page 4 and 5 specifically) Option 1 mitigates the emission factors using the number of "wet days" in the period and Option 2 mitigates the factors using the number of "wet hours" in the period. PM10 increment modeling is determined on a 24-hour average and annual average. "Wet days" in the period would easily coincide w/ this 24 hour average. So, I would be a proponent of using Option 1 on the basis of "wet days" in the period.

Michelle Chang